New Jersey Space Grant at Stevens Institute of Technology

Conceptual Design Review

Stevens Institute of Technology

Sponsored by the New Jersey Space Grant

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Pt. 1 - Vibration Isolation

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George-Douglas Price, Nathan Smith, Jesse Stevenson,
Adam Testa, Sam Yakovlev, Zachary Shoop
PDR Presentation Contents

• Section 1: Mission Overview
  – Mission Overview
  – Theory and Concepts
  – Minimum Success Criteria
  – Mission Requirements (detailed)
  – Expected Results
  – Concept of Operations

• Section 2: System Overview
  – Subsystem Definitions
  – System Level Block Diagram
  – Critical Interfaces (ICDs)
  – Ports (if applicable)
  – User Guide Compliance
  – Sharing Logistics (if applicable)

• Section 3: Subsystem Design
  – Electronics and Power System (EPS)
    • EPS Block Diagram
    • EPS Key Trade Studies
    • EPS Risks/Mitigation
  – Software and Data Acquisition (SDA)
    • SDA Block Diagram
    • SDA Key Trade Studies
    • SDA Risks/Mitigation
  – Software and Data Acquisition (STR)
    • STR Block Diagram
    • STR Key Trade Studies
    • STR Risks/Mitigation
  – Software and Data Acquisition (CAI)
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    • CAI Key Trade Studies
    • CAI Risks/Mitigation
PDR Presentation Contents

• Section 4: Prototyping Plan
• Section 5: Project Management Plan
  – Org Chart
  – Schedule
  – Budget
  – Team Contact Matrix
  – Team Availability Matrix
Mission Overview

Stephen Kontrimas
Mission Overview: **Mission Statement**

- Create a system that can record and isolate vibrations occurring in a payload during launch for sensitive electronics and other equipment
- The system will be inexpensive and will consist of commodity hardware in a small footprint
Mission Overview: **Mission Objectives**

- **Objectives**
  - Improve on last year’s design
  - Test new system’s effectiveness and create a reusable electrical system for vibration measurement

- **Project Requirements**
  - Develop a recording mechanism for reading in-flight acceleration data at high rates
  - Test a wider range of passive material
  - Develop mechanical subsystems for dampening vibration
    - For the active system, a set of electronics + microcontroller to react to changes in acceleration
Mission Overview: **Theory and Concepts**

- Vibration will be measured at high (greater than 40 kHz) Hz rates from three-axis accelerometers
- One accelerometer will be used as a control
- Vibrations will be reduced using either passive or active means
  - Active: Similar to camera stabilization
  - Passive: Three-axis system and material-based absorption
ConOps - Vibration Isolation

Stop data collection / vibration isolation
$t \approx 1.3 \text{ min}$
Altitude: 75 km

$-$G switch triggered
$-$All systems on
$-$Begin recording + vibration isolation

Apogee
$t \approx 2.8 \text{ min}$
Altitude: $\approx 115 \text{ km}$

End of Orion Burn – Spin Rate Largest
$t \approx 0.6 \text{ min}$
Altitude: 52 km

High Tumble Rate
$t \approx 4.0 \text{ min}$
Altitude: 95 km

Low N2, Low spin
$t \approx 5.5 \text{ min}$
Chute Deploys

Splash Down
$t \approx 15 \text{ min}$

T = -3 min
Power on hardware
Mission Overview: **Success Criteria**

- **Minimum Success Criteria**
  - Data that can be compared with last year

- **Comprehensive Success Criteria**
  - Comparable results between control and isolated vibration recordings
  - Equipment reusable for future launches
  - Better vibration reduction than previous experiment (measured by % difference)
Mission Overview: **Expected Results**

- Be able to compare results recorded from onboard electronics (SD card)
- Noticeable reduction in jerk (change in acceleration)
  - Better reduction than last year (measured by %)
- Would permit launch of more precise payloads (i.e. mass spectrometers)
## Example Functional Requirements:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active System will adjust actuators to mitigate vibration.</td>
<td>Demonstration</td>
<td>The active system will adjust its actuators to better act against vibration, using an algorithm to process current data during acquisition.</td>
</tr>
<tr>
<td>The data will be sampled at a rate of 44 kHz and be recorded on an SD (or micro SD) card(s).</td>
<td>Analysis</td>
<td>The system will sample at the Nyquist frequency required to obtain clear readings from all channels from all accelerometers.</td>
</tr>
<tr>
<td>The code will run off of a microcontroller.</td>
<td>Demonstration</td>
<td>The gathering/processing code will run without an OS present (to minimize delay) and without human input.</td>
</tr>
<tr>
<td>The passive materials will be mounted without causing interference to other systems.</td>
<td>Test</td>
<td>Passive materials will be aligned together, and positioned so that they will not interfere with the active system or electronics.</td>
</tr>
<tr>
<td>Electronics will be managed and integrated in a neat and orderly manner.</td>
<td>Inspection</td>
<td>Mounting, electronics connections and cable management will be done efficiently to save space and make internal components easy to access and modify.</td>
</tr>
</tbody>
</table>
De-Scopes & Off-Ramps

• If three-axis accelerometers are not usable, then single-axis accelerometers will be used instead
  • Already in use - active system will only be 2 axis mostly due to space constraints
• If new passive materials cannot be obtained, same materials as last year’s experiment will suffice
System Overview

Stephen Kontrimas
System Definitions

• Subsystems
  • STR: Structures (including passive isolation)
  • EPS: Electrical and Power System
  • SDA: Software and Data Analysis
  • CAI: Controlled Active Isolator
  • MaPS: Magnetic Passive System
System Level Block Diagram
System Design - Internal Physical Model Drawing

All measurements are in inches.
System Design - Magnetic Passive Isolation System
## User Guide Compliance: Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; mid-can?</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>Contained in can</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>Connected to can by 4/5 bulkheads on top and bottom only</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>Mass at 20±0.2lbs</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>Shared canister clearance</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>No voltage on the can</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>No voltage on multipurpose port</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>Activation wires at least 4 ft</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>Activation wire at least 24 gauge</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>Early Activation: current &lt; 1 A</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>T-0 Activation: current &lt; .1 A</td>
<td>Do not know yet, but we intend to</td>
</tr>
<tr>
<td>Battery Type</td>
<td>Lithium Polymer (will not charge at Wallops)</td>
</tr>
</tbody>
</table>
Design Overview: Shared Can Logistics

• Hobart and William Smith Colleges’ Goals:
  – 1) Measure muon flux at different levels in the atmosphere.
  – 2) Model Earth's magnetic field with respect to altitude.
  – 3) To get local students

• Plan for collaboration
  – Communicate by Email
  – Plan to share CAD models

• Plan to use mid plate

• Who needs what port?
  – Need to follow up on this
Subsystem Design
EPS: Electrical and Power System
Jesse Stevenson
EPS: Design Requirements

- The power supply of this year’s RockSAT project is similar to last year’s power supply
- 3 or 6 LiPo Packs to give 12V (3 in series, or 2x3 in series)
- Amperage should be around 2A based on last year’s estimates
- Power shall be controlled by a MOSFET
- Must regulate power down to 5V for each microcontroller (one regulator for each team for independence)
EPS: Batteries

• All batteries are the recycled LiPo cells we have from last year
## EPS: Battery Trade Study

<table>
<thead>
<tr>
<th>Battery Type:</th>
<th>LiPo</th>
<th>NiCd/NiHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (inverted scale)</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Availability</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Capacity</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Power to Weight Ratio</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Shape</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Charging at Wallops</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Average</td>
<td>7.3</td>
<td>6.8</td>
</tr>
</tbody>
</table>
## EPS: Accelerometer Trade Study

<table>
<thead>
<tr>
<th>Accelerometer Type:</th>
<th>IS16223</th>
<th>AD</th>
<th>IS16227</th>
<th>AD</th>
<th>ADXL001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (inverted scale)</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onboard Data Processing</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional Components Required (inverted)</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>6.4</td>
<td>6.2</td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Power System Risk Matrix

PS.RSK.1: No data is collected IF MOSFET Doesn’t turn on or power isn’t connected
PS.RSK.2: Payload loses power IF MOSFET Overheats or is overloaded
PS.RSK.3: Mission objective isn’t reached IF batteries are shorted
Subsystem Design
SDA: Software and Data Analysis
Sam Yakovlev
SDA: Design Requirements

- Gather data from all accelerometers, and use current data to control active isolation system.
- Record Data
  - Record at least 20 kHz sampling rate from the accelerometers at 10-bit resolution
  - Will either record continuously or in 10 second bursts
## SDA: Design Requirements

<table>
<thead>
<tr>
<th>Data Storage:</th>
<th>Raspberry Pi</th>
<th>Beaglebone Black</th>
<th>Other Micro (ARM Processor without OS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (inverted scale)</td>
<td>7</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Availability</td>
<td>9</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Speed</td>
<td>8</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Complexity (inverted scale)</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Average</td>
<td>7.25</td>
<td>7.5</td>
<td>5</td>
</tr>
</tbody>
</table>
SDA: Block Diagram

Start

Collect Data

Process change since last measurement

Determine power to drive actuators to counteract

Drive actuators to counteract

Storage full?

Record Data to Active Isolation Files

Record Data to Passive Isolation Files

Stop

Control Algorithm (subject to change)

Yes

No
### SDA: Trade Studies

- While ARM is potentially the fastest/most efficient, it is also the hardest to work with
- Raspberry Pi is slightly easier to work with, but BeagleBone Black has better functionality with peripherals

<table>
<thead>
<tr>
<th>µController</th>
<th>Pi</th>
<th>BBB</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>7</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Availability</td>
<td>9</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Clock Speed</td>
<td>8</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Peripherals</td>
<td>6</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Programming Language</td>
<td>7</td>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

| **Average:**        | 7.4 | **8.2** | 4.6  |
SDA: Risks

- **Expected Risks:**
  - SDA.RSK.1: Mission objectives not met if a microcontroller cannot be found
  - SDA.RSK.2: Mission objectives are not met if microcontroller begins recording when it shouldn’t
  - SDA.RSK.3: Wiring/other physical issues interrupt data collection

- **Possible fixes**
  - SDA.RSK1: Default to BBB
  - SDA.RSK.2: Implement redundant timed start on data processing/control program
  - SDA.RSK.3: Maintain proper electronics and cable management throughout development process
Subsystem Design
STR: Structures

Aidan Aquino
STR: Design Requirements

- Create a housing for the different passive materials
- Create a mechanical backbone of the experiment allowing for housing of electronic components, including the pressure sensor team
- Choose new material(s) for passive vibration reduction
STR: Block Diagram

- See CAD Model
## STR: Trade Studies (passive materials)

<table>
<thead>
<tr>
<th>Material</th>
<th>Neoprene</th>
<th>Cable Mount</th>
<th>Silicone Gel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>8</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Damping</td>
<td>7</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Ease of Integration</td>
<td>7</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Cost</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td><strong>Average:</strong></td>
<td><strong>7.25</strong></td>
<td><strong>7.5</strong></td>
<td><strong>6</strong></td>
</tr>
</tbody>
</table>
STR: Risks

- **Expected Risks:**
  - STR.RSK.1: Nuts unscrew due to vibrations
  - STR.RSK.2: Electronics with voltage on the can
  - STR.RSK.3: Failure of Mechanical Backbone

- **Possible fixes**
  - STR.RSK1: Use nylon nuts and locktight
  - STR.RSK.2: put electrical tape on all electronics
  - STR.RSK.3: Vibration testing
Subsystem Design
CAI: Controlled Active Isolator

Stephen Kontrimas
CAI: Design Requirements

- Take feedback from the accelerometer and compensate for vibrations
- Use some kind of actuator to achieve vibration isolation in the 2D plane defined by the top plate of the canister
CAI: Block Diagram

- Show the subsystem block diagram with primary component choices highlighted.

Control System Block Diagram:

Accelerometer Input → Algorithm → Actuators → Accelerometer Output

Closed loop feedback system used a the students are most familiar with this kind of system. As more work is done it may evolve, as will the algorithm.
<table>
<thead>
<tr>
<th>Type of Actuator</th>
<th>Push-Pull Solenoid</th>
<th>Two Track Actuator</th>
<th>Double Jointed Actuator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost:</td>
<td>10</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Availability:</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Max Force:</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Size:</td>
<td>10</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Complexity:</td>
<td>10</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Stock Range:</td>
<td>3</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td><strong>Average:</strong></td>
<td><strong>8</strong></td>
<td><strong>8.5</strong></td>
<td><strong>9.2</strong></td>
</tr>
</tbody>
</table>
CAI: Risks

Expected Risks:

- **CAI.RSK.1**: Catastrophic actuator failure causing damage to the rest of the payload.
- **CAI.RSK.2**: Actuator Misalignment causing isolation to not correctly isolate vibrations
- **CAIRSK3**: System is unstable

Possible fixes:

- **CAI.RSK.1**: Place an extra piece of acrylic in between the active and the rest of the payload
- **CAI.RSK.2**: Extensive testing to ensure that the actuator is properly aligned
- **CAI.RSK.3**: Extensive testing and careful system design
Test/Prototyping Plan

Jesse Stevenson
Prototyping Plan

**Risk/Concern**

- **STR/CAI**: Mounting everything within canister.
- **SDA**: Improper timing of data collection resulting in useless data.
- **EPS**: Power system inadequate for payload demands.

**Action**

- **Finalize CAD model with everything needed**
- **Program failsafe start timer to collect around proper time**
- **Extensive testing of all loads and full system test runs**
## Testing/Prototyping Example

<table>
<thead>
<tr>
<th>Test</th>
<th>How</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration (For structural purposes)</td>
<td>Using a vibration table at Stevens and again at Wallops to test hardware rigidity</td>
<td>Ensure that the payload can handle the vibrations of launch and re-entry.</td>
</tr>
<tr>
<td>Data Acquisition</td>
<td>Run multiple successful data collection trials, under several operating conditions (some channels disconnected, different frequencies, with SD card nearly full)</td>
<td>Ensure that all electronics and software can interface and collect data, and maximizes useful data collection even in unlikely bad conditions. Also gives opportunity to test Active system.</td>
</tr>
</tbody>
</table>
Project Management Plan

George-Douglas Price
<table>
<thead>
<tr>
<th>Task Name</th>
<th>Start</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoDR Teleconference</td>
<td>Thu 10/12/17</td>
<td>Thu 10/12/17</td>
</tr>
<tr>
<td>Earnest Payment of $1000 Due</td>
<td>Fri 10/13/17</td>
<td>Fri 10/13/17</td>
</tr>
<tr>
<td>Basic Recording Program</td>
<td>Thu 10/19/17</td>
<td>Thu 10/19/17</td>
</tr>
<tr>
<td>Preliminary Design Review (PDR) Teleconference</td>
<td>Mon 10/30/17</td>
<td>Fri 11/3/17</td>
</tr>
<tr>
<td>MATLab Data Analysis Program</td>
<td>Tue 11/21/17</td>
<td>Tue 11/21/17</td>
</tr>
<tr>
<td>Preliminary Cannister Set Up</td>
<td>Sun 11/26/17</td>
<td>Sun 11/26/17</td>
</tr>
<tr>
<td>Prototype Electrical Design</td>
<td>Thu 11/30/17</td>
<td>Thu 11/30/17</td>
</tr>
<tr>
<td>Obtain All Parts</td>
<td>Fri 12/1/17</td>
<td>Fri 12/1/17</td>
</tr>
<tr>
<td>Finalize Mechanical Portion</td>
<td>Mon 12/25/17</td>
<td>Mon 12/25/17</td>
</tr>
<tr>
<td>Electronic Design and Schematic</td>
<td>Thu 12/28/17</td>
<td>Thu 12/28/17</td>
</tr>
<tr>
<td>Final Down Select- Flights Awarded</td>
<td>Wed 1/10/18</td>
<td>Wed 1/10/18</td>
</tr>
<tr>
<td>Progress Update Telecon</td>
<td>Sun 1/22/17</td>
<td>Thu 1/26/17</td>
</tr>
<tr>
<td>Finish Cannister Construction</td>
<td>Thu 2/1/18</td>
<td>Thu 2/1/18</td>
</tr>
<tr>
<td>Final Payment due</td>
<td>Mon 4/2/18</td>
<td>Mon 4/2/18</td>
</tr>
<tr>
<td>Subsystem Testing Review Teleconference</td>
<td>Mon 2/12/18</td>
<td>Fri 2/16/18</td>
</tr>
<tr>
<td>Event</td>
<td>Start Date</td>
<td>End Date</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Progress Update Telecon</td>
<td>Mon 3/5/18</td>
<td>Fri 3/9/18</td>
</tr>
<tr>
<td>Integrated Subsystem Testing Review Teleconference</td>
<td>Mon 3/26/18</td>
<td>Fri 3/30/18</td>
</tr>
<tr>
<td>Final Payment due</td>
<td>Mon 4/2/18</td>
<td>Mon 4/2/18</td>
</tr>
<tr>
<td>RockSat Payload Canister sent to customers (pending receipt of final payment)</td>
<td>Mon 4/9/18</td>
<td>Mon 4/9/18</td>
</tr>
<tr>
<td>Progress Update Telecon</td>
<td>Mon 4/9/18</td>
<td>Fri 4/13/18</td>
</tr>
<tr>
<td>Full Mission Simulation Test Report Presentation Telecon</td>
<td>Mon 4/30/18</td>
<td>Fri 5/4/18</td>
</tr>
<tr>
<td>Progress Update Telecon</td>
<td>Mon 5/21/18</td>
<td>Fri 5/25/18</td>
</tr>
<tr>
<td>Possible Program Telecon</td>
<td>Wed 5/30/18</td>
<td>Wed 5/30/18</td>
</tr>
<tr>
<td>Travel to Wallops Flight Facility</td>
<td>Wed 6/13/18</td>
<td>Wed 6/13/18</td>
</tr>
<tr>
<td>Visual Inspections at Refuge Inn</td>
<td>Thu 6/14/18</td>
<td>Thu 6/14/18</td>
</tr>
<tr>
<td>Vibration/Integration at Wallops</td>
<td>Fri 6/15/18</td>
<td>Mon 6/18/18</td>
</tr>
<tr>
<td>Presentations to Next Year's RockSat</td>
<td>Wed 6/20/18</td>
<td>Wed 6/20/18</td>
</tr>
<tr>
<td>Launch Day</td>
<td>Thu 6/21/18</td>
<td>Thu 6/21/18</td>
</tr>
<tr>
<td>Preliminary Launch Results Document Due</td>
<td>Fri 7/13/18</td>
<td>Fri 7/13/18</td>
</tr>
<tr>
<td>Final Report Due</td>
<td>Fri 7/27/18</td>
<td>Fri 7/27/18</td>
</tr>
</tbody>
</table>
## Preliminary Budget

### Vibration Isolation Team Planned Operating Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Cost per Item: (dollars)</th>
<th>Total Cost:</th>
<th>Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td>3</td>
<td>$24.55</td>
<td>$73.65</td>
<td><a href="https://www.makergeeks.com/collections/pla-filament-1-75mm/products/maker-series-pla-3d-filament-175mm-dark-as-night-black-1kg">https://www.makergeeks.com/collections/pla-filament-1-75mm/products/maker-series-pla-3d-filament-175mm-dark-as-night-black-1kg</a></td>
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<td>Polymagnets</td>
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<td>$14.00</td>
<td>$84.00</td>
<td><a href="http://catalog.polymagnet.com/1002285.html">http://catalog.polymagnet.com/1002285.html</a></td>
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<td>ADIS16223 3-Axis Accelerometers</td>
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<td>$247.61</td>
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<td><a href="https://www.digikey.com/short/qt5hnq">https://www.digikey.com/short/qt5hnq</a></td>
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<td>Beaglebone black</td>
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<td>$63.00</td>
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<td>Active Actuator (assumed)</td>
<td>2</td>
<td>$100.00</td>
<td>$200.00</td>
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</tr>
<tr>
<td>standoffs (approximately)</td>
<td>10</td>
<td>$1.00</td>
<td>$10.00</td>
<td><a href="https://www.homedepot.com/s/bolt%2520spacers?NCNI-5">https://www.homedepot.com/s/bolt%2520spacers?NCNI-5</a></td>
</tr>
<tr>
<td>nuts and bolts (approximately)</td>
<td>5</td>
<td>$5.00</td>
<td>$25.00</td>
<td><a href="https://www.homedepot.com/s/nuts?NCNI-5">https://www.homedepot.com/s/nuts?NCNI-5</a></td>
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<tr>
<td>Acrylic Sheet</td>
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<td>$105.00</td>
<td>$105.00</td>
<td><a href="https://www.homedepot.com/p/Plexiglas-24-in-x-48-in-x-0-12-5-in-Acrylic-Sheet-4-Pack-MC2448125/206855693">https://www.homedepot.com/p/Plexiglas-24-in-x-48-in-x-0-12-5-in-Acrylic-Sheet-4-Pack-MC2448125/206855693</a></td>
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<td><strong>Total</strong></td>
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<td><strong>$1,551.09</strong></td>
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### Team Contact Matrix: Vibration Isolation Team

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Role/Position</th>
<th>Email Address</th>
<th>Phone Number</th>
<th>US Citizen? (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adam Testa</td>
<td>Vibrations Team</td>
<td><a href="mailto:atesta@stevens.edu">atesta@stevens.edu</a></td>
<td>1-862-207-2069</td>
<td>Yes</td>
</tr>
<tr>
<td>Aidan Aquino</td>
<td>Vibrations Team</td>
<td><a href="mailto:aaquino@stevens.edu">aaquino@stevens.edu</a></td>
<td>856-630-5011</td>
<td>Yes</td>
</tr>
<tr>
<td>George-Douglas Price</td>
<td>Vibrations Team</td>
<td><a href="mailto:gprice@stevens.edu">gprice@stevens.edu</a></td>
<td>201-920-9358</td>
<td>Yes</td>
</tr>
<tr>
<td>Jesse Stevenson</td>
<td>Vibrations Team</td>
<td><a href="mailto:jstevens@stevens.edu">jstevens@stevens.edu</a></td>
<td>732-567-2760</td>
<td>Yes</td>
</tr>
<tr>
<td>Pablo del Puerto</td>
<td>Vibrations Team</td>
<td><a href="mailto:pdelpuer@stevens.edu">pdelpuer@stevens.edu</a></td>
<td>201-982-1294</td>
<td>Yes</td>
</tr>
<tr>
<td>Sam Yakovlev</td>
<td>Vibrations Team</td>
<td><a href="mailto:syakovle@stevens.edu">syakovle@stevens.edu</a></td>
<td>862-221-1963</td>
<td>Yes</td>
</tr>
<tr>
<td>Stephen Kontrimas</td>
<td>Vibrations Team</td>
<td><a href="mailto:skontrim@stevens.edu">skontrim@stevens.edu</a></td>
<td>1-781-742-5865</td>
<td>Yes</td>
</tr>
<tr>
<td>Nathan Smith</td>
<td>Vibrations Team</td>
<td><a href="mailto:nsmith5@stevens.edu">nsmith5@stevens.edu</a></td>
<td>732-754-1509</td>
<td>Yes</td>
</tr>
<tr>
<td>Andrew Afflitto</td>
<td>Vibrations Team</td>
<td><a href="mailto:aafflitt@stevens.edu">aafflitt@stevens.edu</a></td>
<td>862-228-3956</td>
<td>Yes</td>
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<tr>
<td>Joshua Gross</td>
<td>Vibrations Team</td>
<td><a href="mailto:jgross@stevens.edu">jgross@stevens.edu</a></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Alexis Paolella</td>
<td>Vibrations Team</td>
<td><a href="mailto:apaolell@stevens.edu">apaolell@stevens.edu</a></td>
<td>908-674-2014</td>
<td>Yes</td>
</tr>
<tr>
<td>Joseph S. Miles</td>
<td>Professor</td>
<td><a href="mailto:jmiles@stevens.edu">jmiles@stevens.edu</a></td>
<td>1-201-216-8964</td>
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</table>
## Team Availability Matrix

<table>
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<tr>
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<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
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<tr>
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<td></td>
</tr>
<tr>
<td>10</td>
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<td></td>
<td></td>
<td>ok</td>
<td>ok</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Risks and Worries

- Last year the team had an issues with time and deadlines
- Lack of communication between departments led to Jesse Stevenson taking on the bulk of the work
  – Better organization this time around
- At the moment we are using a solenoid for the CAI - not ideal
Conclusion

- Perform preliminary tests on electronic
- Finalize Passive Materials
- Finalize Mechanical Design
- Managing time well with meetings

Issues:
- Finding an appropriate actuator for the CAI that fits in the allotted space
PDR Presentation Contents

• Section 1: Mission Overview
  – Mission Overview
  – Theory and Concepts
  – Mission Requirements
  – Expected Results
  – Concept of Operations

• Section 2: System Overview
  – Subsystem Definitions
  – System Level Block Diagram
  – Critical Interfaces and Ports
  – Sharing Logistics
PDR Presentation Contents

• Section 3: Subsystem Design
  – Electrical and Power System (EPS)
    • EPS Block Diagram
    • EPS Key Trade Studies
    • Subsystem Risks/Mitigation
  – Structures (STR)
    • STR Block Diagram
    • STR Key Trade Studies
    • Subsystem Risks/Mitigation
PDR Presentation Contents

• Section 5: Prototyping Plan
  – Testing
  – Analysis
  – Mounting

• Section 6: Project Management Plan
  – Org. Chart
  – Schedule
  – Budget
  – Team Contact Matrix
Mission Overview

Richard Thornton
Mission Overview: **Mission Statement**

The goal of this project is to measure High-Speed Boundary Layer Transitions from laminar to turbulent pressure waves using *multiple high frequency* pressure sensors mounted in a custom window on the skin of the rocket.

*This is a repeat project - design has been altered.*
Mission Overview: **Theory and Concepts**

- **High Velocity Boundary Layer Transition**
  - Laminar $\rightarrow$ Unstable $\rightarrow$ Turbulent
  - Measure transition using static pressure sensors perpendicular to the airflow

- **Laminar to Turbulent transition in High Velocity Boundary layers** helps to predict and control properties such as:
  - Heat transfer
  - Skin friction
Sensor location crucial → pressure is higher near "neck" of rocket than at the center of the shock wave near the tip

○ Transition phase more predominant near this location
Mission Overview: Previous Research

• Considerable prior research has been conducted on Boundary Layer Transitions → Costly data capture methods
  – High speed wind tunnels, military aircraft/rockets
  – Gathering real-world data is valuable
    • Furthers understanding of BL Transitions → increase vehicle performance
    • Determine methods for improving cost effectiveness

• For this project, primary sources of research included:
  – Boundary Layer Transition in High-Speed flows due to roughness
    • Prahladh S. Iyer, Suman Muppidi & Krishnan Mahesh
  – Flight Data for Boundary-Layer Transition at Hypersonic and Supersonic Speeds
    • Steven P. Schneider
  – Development of Hypersonic Quiet Tunnels
    • Steven P. Schneider
  – 2016, 2017 Stevens RockSAT-C Experiment
Mission Overview: **Mission Objectives**

- **Objectives**
  - Measure and record pressure data along surface of launch vehicle using:
    - 2 high frequency pressure sensors

- **Goals**
  - Characterize the transition phases of the boundary layer through various pressures/velocities along the surface of the vehicle
Mission Overview: **Expected Results**

- Boundary Layer Transitions:
  - The static pressure will reflect the transition of the boundary layer
  - When in the Laminar phase (subsonic), there will be little change in static measurement
  - At Mach 1 there should be a sudden increase in static pressure followed by little to mild consistent fluctuations on the order of $10^1$ kPa (supersonic Laminar)
  - Once the flow is fully Turbulent there will be considerable fluctuations in the static pressure on the order of $10^{2-3}$ kPa
Mission Overview: Comprehensive Success Criteria

- Minimum Success Criteria
  ○ Successfully sample dynamic surface flow at a minimum of 25% the targeted sample rate and with at least 8-bit resolution within the window of interest

- Comprehensive Success Criteria
  ○ Successfully sample dynamic surface flow at 2 MHz with 16-bit resolution within the window of interest (180-200 seconds)
    ■ Expect to measure instability waves using the pressure fluctuations on the boundary layer of the launch vehicle at the given resolution and sampling rate
ConOps - Pressure Sensor

- **High Tumble Rate**
  - $t \approx 4.0$ min
  - Altitude: 95 km

- **Apogee**
  - $t \approx 2.8$ min
  - Altitude: ~115 km

- **End of Orion Burn – Spin Rate Largest**
  - $t \approx 0.6$ min
  - Altitude: 52 km

- **Low N2, Low spin**
  - $t \approx 5.5$ min
  - Chute Deploys

- **Pressure sensor data capture end**
  - $t \approx 2.5$ min
  - Altitude: ~100 km

- **Splash Down**
  - $t \approx 15$ min

- **-G switch triggered**
  - All systems on
  - Begin recording pressure data

- **T = -3min**
  - Power on hardware

- **Altitude**
Mission Overview: **Mission Requirements**

1. The pressure sensors shall be exposed to the atmosphere flush with the skin of the launch vehicle - ideally towards the top
   a. A window space will be required to facilitate this

2. Data shall be recorded prior to and during the period of interest
   a. Period of interest is when the rocket is approaching Mach 4
   b. Ideally, data will be recorded beginning just prior to launch, through at least 180-200 seconds of flight

3. Mission requires useable, high-fidelity data to be available upon rocket recovery
   a. Current goals for sample rate and resolution are 1-2 MHz and 16-bits for the high frequency sensors
Mission Overview: **Functional Requirements**

- **FUNC.REQ.1**: Accurate and precise collection of data from pressure sensors.

- **FUNC.REQ.2**: Functional watertight pressure sensor mounting design to minimize any noise in pressure readings.

- **FUNC.REQ.3**: Ensure protocol for storage system that can store data for required window and convert A to D in real time.
Mission Overview: **Functional Requirements**

- **DES.REQ.1:** A Low and High Frequency pressure sensor combination will collect data at a resolution of 16 bits.

- **DES.REQ.2:** Proper milling and design of window. Noise can extend from the pressure sensor cavity and placement. Flush placement of pressure sensor.

- **DES.REQ.3:** The ADC will convert the data at 2MHz. The ADC and Microcontroller must support this rate. Storage capacity must be at least 1.5-2GB with margin.
# Functional Requirements Verification

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<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>FUNC.REQ.1</td>
<td>Test</td>
<td>Pre-Flight bench testing by wiring all sensors to the ADC and Microcontroller</td>
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<tr>
<td>FUNC.REQ.2</td>
<td>Inspection</td>
<td>Inspect for watertightness after underwater submission during preflight testing. Mathematical analysis on the noise that may be recorded due to cavity resonance can verify best location for sensors</td>
</tr>
<tr>
<td>FUNC.REQ.3</td>
<td>Test</td>
<td>Pre-Flight bench test</td>
</tr>
</tbody>
</table>
Mission Overview: **De-Scope & Off-ramps**

- **Budget Restrictions**: Reuse the high frequency pressure sensor
  - If sensor is viable, only required to purchase one additional high frequency pressure sensors
  - If not viable, incur charges based on repairs or re-purchase (up to $600)

- **Sampling rate**: 2 MHz sampling rate might not be achieved
  - Limited experience in data capture in past
  - Not considered a high risk.

- **Size**: Experiment should fit on a single disk in the payload
  - Combination of all the electronics on shared plate might be excessive
  - Smaller electronics usually have greater cost
    - Balance budget and size
System Overview

Richard Thornton
System Overview: **System Definitions**

- **SS1 - Electrical and Power System (EPS)**
  - Pressure Sensors
  - DAQ/Microcontroller - Beaglebone/PRUDAQ
  - Filters & Amplifiers - Signal Conditioner
  - PSU

- **SS2 - Structures (STR)**
  - Sensor Mounting - Port
  - Cable and Elec. Component Management
Sensors mounted to window and flush with exterior of launch vehicle. Require airtight seal.

Wires run from canister to specialized window mount.

Plate mounted to bottom of canister on standoffs. Sensitive equipment mounted with vibration dampeners directly to plate.

RockSat-C 2018
PDR
System Overview: **Physical Model**

- **Port Pocket**
- **Port Window**
  - (2 Sensor Mounting Holes)
- **Dual SMA Connectors**
## System Overview: Ports and Logistics

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; mid-can?</td>
<td>TBD</td>
</tr>
<tr>
<td>Contained in can</td>
<td>Yes, unconfirmed</td>
</tr>
<tr>
<td>Connected to can by 4/5 bulkheads on top and bottom only</td>
<td>TBD</td>
</tr>
<tr>
<td>Mass at 20±0.2lbs</td>
<td>TBD</td>
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<tr>
<td>Shared canister clearance</td>
<td>Yes, unconfirmed</td>
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<tr>
<td>No voltage on the can</td>
<td>TBD</td>
</tr>
<tr>
<td>No voltage on multipurpose port</td>
<td>TBD</td>
</tr>
<tr>
<td>Activation wires at least 4 ft</td>
<td>TBD</td>
</tr>
<tr>
<td>Activation wire at least 24 gauge</td>
<td>TBD</td>
</tr>
<tr>
<td>Early Activation: current &lt; 1 A</td>
<td>TBD</td>
</tr>
<tr>
<td>T-0 Activation: current &lt; .1 A</td>
<td>TBD</td>
</tr>
<tr>
<td>Battery Type</td>
<td>Lithium Polymer (will not charge at Wallops)</td>
</tr>
</tbody>
</table>

---

**Requirement**

- **Center of gravity in 1" mid-can?**
- **Contained in can**
- **Connected to can by 4/5 bulkheads on top and bottom only**
- **Mass at 20±0.2lbs**
- **Shared canister clearance**
- **No voltage on the can**
- **No voltage on multipurpose port**
- **Activation wires at least 4 ft**
- **Activation wire at least 24 gauge**
- **Early Activation: current < 1 A**
- **T-0 Activation: current < .1 A**
- **Battery Type**

**Status/Reason (if needed)**

- TBD
- Yes, unconfirmed
- TBD
- TBD
- Yes, unconfirmed
- TBD
- TBD
- TBD
- TBD
- Lithium Polymer (will not charge at Wallops)
Subsystem Design
Electrical and Power System (EPS)

Chris Blackwood
EPS: Design Requirements

• Overview
  – Components
    • Sensors
    • DAQ and Microcontroller
      – Beaglebone and Beaglebone PRUDAQ
    • Filters and Signal Conditioner
    • Batteries and Power Supply System
  – Functions
    • Memory management and storage
    • Post collection filtering
EPS: Design Requirements

• Design Requirements
  – EPS.REQ.1: The pressure sensors are to sample at a 2 MHz sample rate with a resolution of 16 bits.
  – EPS.REQ.2: The ADC and Microcontroller must translate and record the data to memory at a higher enough rate to avoid data loss.
  – EPS.REQ.3: The data must be timestamped using a Real Time Clock prior to transfer into memory
EPS: Block Diagram

- Brief explanation
  - Raw signal data from sensor filtered and amplified.
  - 16 bit ADC converts amplified signal to digital; for the beaglebone.
  - A series of on board RAM and a flash drive for permanent storage on which further study is to be done.
## Signal Conditioner

<table>
<thead>
<tr>
<th></th>
<th>Prebuilt Industry Standard</th>
<th>Custom Signal Conditioner</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>6 (High)</td>
<td>10 (Very Low)</td>
</tr>
<tr>
<td><strong>Development Time</strong></td>
<td>10 (plug and play)</td>
<td>7</td>
</tr>
<tr>
<td><strong>Desired Cutoff Freq</strong></td>
<td>6 (may be difficult to find what we need)</td>
<td>10</td>
</tr>
<tr>
<td><strong>Robustness</strong></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>8</td>
<td>9.25</td>
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## Microcontroller

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<tr>
<th></th>
<th>Beaglebone PRUDAQ</th>
<th>DIY</th>
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<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>10 ($140)</td>
<td>10 (~$130)</td>
</tr>
<tr>
<td><strong>RAM</strong></td>
<td>10 (Onboard)</td>
<td>8 (Externally interfaced)</td>
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<tr>
<td><strong>Development Time</strong></td>
<td>9 (Short)</td>
<td>3 (Long)</td>
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<tr>
<td><strong>Resolution</strong></td>
<td>6 (10 bit ADC)</td>
<td>10 (16 bit ADC)</td>
</tr>
<tr>
<td><strong>Probability of Success</strong></td>
<td>9 (High)</td>
<td>3 (Medium-low)</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>8.8</td>
<td>6.8</td>
</tr>
</tbody>
</table>
EPS: Risks

Expected Risks:
- EPS.RSK.1: System begins sampling at wrong time
- EPS.RSK.2: Vibration causes connectors or USB drive to slip loose

Mitigation:
- EPS.RSK.1: Utilize the G-switch and onboard accelerometer to begin sampling
- EPS.RSK.2: Create strong structural support for all connectors (improvement on previous year)
Subsystem Design
Structural System (STR)

Omkar Desai
STR: Design Requirements

• Overview
  – Creation of pressure sensor mounting block to connect to \textit{Window Pocket} → milling of sensor holes in \textit{Window}
  – Ensures flush mounting of sensors for accurate reading

• Design Requirements
  – STR.REQ.1: The pressure sensors must be mounted flush with the skin of the rocket with an appropriate sized opening
  – STR.REQ.2: The window of the rocket must be pierced and must be airtight to conform to design requirements and prevent water from entering the modules on landing
  – STR.REQ.3: Proper mounts for the sensors are required to be designed and machined (threaded).
STR: Risks

Expected Risks:
- STR.RSK.1: Waterproofing failure
- STR.RSK.2: Measurement objectives fails due to vibrations and shock created by supersonic flight.
- STR.RSK.3: Over mass or size limit

Mitigation:
- STR.RSK.1: Lower error tolerance in sensor piercing other parts
- STR.RSK.2: Reduce vibrations and chance of shortages/detachments
- STR.RSK.3: Develop CAD models and conduct multiple prototype tests
Test/Prototyping Plan

Ronald Ankner
Prototyping Plan

- Test various subsystem setups
  - Essentially using different micro-controllers, signal conditioners, and other components to determine what will work best for this application
  - Also estimate which setup can withstand the forces endured in the rocket
- Analyze spatial relations in Solidworks
- Sensor mount prototyping
  - Create test mounts out of wood/plastic to test orientation and security
- Coordinate with vibrations team to configure canister layout
Prototyping Plan Cont.

**Risk/Concern**

- **Testing**: Processor will not collect data at an appropriate rate
- **Analysis**: Data filter filters out necessary data of flight rather than noise
- **Mounting**: Need secure mounting system to ensure stable positioning during flight and eliminate possible wiring issues

**Action**

- Test various setups/DAQs under simulated flight conditions
- Analyze data during and after testing to verify proper filtering
- Prototype multiple mounting systems including the mounting method and material
Project Management Plan

Chris Cowan
Schedule

Nov. 1  PDR Presentation

Nov. 8  Finalize research of components and purchase

Nov. 15-22  Perform testing on subsystem components

Nov. 23-30  Analyze data acquired from testing and compare components

Nov. 30  Finalize component selection for CDR

Dec. 6  CDR presentation

Dec. 20  Adjust subsystem requirements based on CDR

By Jan. 1  Purchase components

Jan. 1 and on  Assuming approval, begin build process
Team Organization Chart

RockSAT-C Rep: Audrey Viland

Faculty Supervisor: Prof. Joseph Miles

Project Advisor: Prof. Nick Parizale

Mechanical:
- Team Lead: Richard Thornton
  - Chris Cowan
  - Helen Yunji
  - Nick O’Friel

Electrical:
- Team Lead: Ronnie Ankner
  - Chris Blackwood
  - Omkar Desai
  - Vinay Jayaram

RockSat-C 2018
PDR
# Budget

<table>
<thead>
<tr>
<th>Task</th>
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<tbody>
<tr>
<td><strong>Electrical</strong></td>
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<tr>
<td>Microcontroller</td>
<td>Beaglebone Black</td>
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</tr>
<tr>
<td></td>
<td>Beaglebone Black PRUDAQ Cape</td>
<td></td>
</tr>
<tr>
<td>Signal Conditioner</td>
<td>TBD</td>
<td>~$200</td>
</tr>
<tr>
<td>External Data Storage</td>
<td>Samsung MUF-64BB/AM flash Drive</td>
<td>~$25</td>
</tr>
<tr>
<td>Power Source/Batteries</td>
<td>TBD</td>
<td>~$100</td>
</tr>
<tr>
<td>High Frequency Pressure Sensor</td>
<td>PCB Piezoelectric Pressure Sensor</td>
<td>~$600</td>
</tr>
<tr>
<td>Miscellaneous (Wiring, Solder, Boards)</td>
<td>Printed Circuit Boards</td>
<td>~$150</td>
</tr>
<tr>
<td><strong>Mechanical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister</td>
<td>TBD</td>
<td>$0</td>
</tr>
<tr>
<td>Miscellaneous (Mounting fixtures, vibration dampeners, etc.)</td>
<td>TBD</td>
<td>~$75</td>
</tr>
<tr>
<td><strong>Total Without Margin</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total With Margin (25%)</strong></td>
<td></td>
<td>~$1,290</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~$1,613</td>
</tr>
</tbody>
</table>
# Team Contact Matrix: **Pressure Sensor Team**

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Role/Position</th>
<th>Email Address</th>
<th>Phone Number</th>
<th>US Citizen? (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ronald John Ankner Jr.</td>
<td><strong>Pressure Sensor Team</strong></td>
<td><a href="mailto:rankner@stevens.edu">rankner@stevens.edu</a></td>
<td>973-864-0251</td>
<td>Yes</td>
</tr>
<tr>
<td>Richard Thornton</td>
<td><strong>Pressure Sensor Team</strong></td>
<td><a href="mailto:rthornto@stevens.edu">rthornto@stevens.edu</a></td>
<td>732-895-8508</td>
<td>Yes</td>
</tr>
<tr>
<td>Chris Blackwood</td>
<td><strong>Pressure Sensor Team</strong></td>
<td><a href="mailto:cblackwo@stevens.edu">cblackwo@stevens.edu</a></td>
<td>908-319-5211</td>
<td>Yes</td>
</tr>
<tr>
<td>Helen Kim</td>
<td><strong>Pressure Sensor Team</strong></td>
<td><a href="mailto:ykim13@stevens.edu">ykim13@stevens.edu</a></td>
<td>201-580-8036</td>
<td></td>
</tr>
<tr>
<td>Chris Cowan</td>
<td><strong>Pressure Sensor Team</strong></td>
<td><a href="mailto:ccowan@stevens.edu">ccowan@stevens.edu</a></td>
<td>267-644-6460</td>
<td>Yes</td>
</tr>
<tr>
<td>Omkar Desai</td>
<td><strong>Pressure Sensor Team</strong></td>
<td><a href="mailto:odesai1@stevens.edu">odesai1@stevens.edu</a></td>
<td>1-551-234-1379</td>
<td></td>
</tr>
<tr>
<td>Vinay Jayaram</td>
<td><strong>Pressure Sensor Team</strong></td>
<td><a href="mailto:vjayara1@stevens.edu">vjayara1@stevens.edu</a></td>
<td>201-423-3944</td>
<td></td>
</tr>
<tr>
<td>Joseph S. Miles</td>
<td><strong>Professor</strong></td>
<td><a href="mailto:jmiles@stevens.edu">jmiles@stevens.edu</a></td>
<td>1-201-216-8964</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Risks & Worries

- Data collection occurs too early in flight
- Faulty wiring
- Signal attenuation or clipping
- Data overload on system
- Fatigue failure in mechanical or electrical systems
Conclusion

• **Mission:**
  – Collect high frequency pressure measurements to analyze the quality of boundary layer flow on the skin of the rocket

• **Issues:**
  – Data quality of signal at roughly 2 MHz
  – Low-Cost, Commercially available System capable of operating at 2 MHz
  – Beginning of data collection

• **Need to determine:**
  – Signal Conditioner Selection